Application of Municipal Solid Waste Compost and Green Manure Exerted Residual Effects on Soil Nutrient Content and Plant Nutrient Uptake in Rice

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ABSTRACT

Aims: Rice is the most widely consumed staple food as well as Bangladesh. With the global upsurge in population, rapid urbanization, and industrialization increasing waste production in urban areas and managing them becoming a major concern. Municipal solid waste (MSW) is considered an important recycling tool for use in agricultural fields as compost. Green manure (GM) is another thing thatprovides a substantial portion of the nitrogen requirement of rice. Both MSW compost and GM add organic matter to the soil. We conducted a study to know the residual effects of municipal solid waste (MSW) compost and green manure (GM) on nutrient contents in soil and uptakes in rice (BINA Dhan-7).

Methods: The experiment was conducted with a Randomized Complete Block Design (RCBD), nine treatments, and three replications. The present rice crop received no fertilizers during the cultivation period. MSW compost and GM inoculated with *Rhizobium* strains were incorporated as per treatments in 2 cycles of the Mungbean- Dhaincha- Rice cropping pattern.

Results: The highest nutrient content and uptake were recorded with higher rates of MSW compost and GM application in the preceding crops. Compost is a slow-release source of nitrogen and most nitrogen remaining after completion of the composting process is bound into organic forms. After application nutrients do not become available immediately for plant uptake, and remain as residue which contributes to improving soil quality for several years after application ceases. MSW compost and GM increases soil nutrient contents, availability, and uptake by adding organic matter, increasing the C: N ratio, and soil’s physical, chemical, and biological properties.

Conclusion: The MSW compost and GM can provide a significant amount of residual effects on the nutrient content in the soil and uptake in rice which depends on the nutrient composition of applied manure in previous crops.

Keywords: Municipal solid waste (MSW) compost, Green manure (GM), *Rhizobium*, Binadhan-7, nutrient content, nutrient uptake.

1. INTRODUCTION

Rice, is the staple crop for more than half the world's population, cultivating more than 100 countries where Asia accounts for 90% of the worldwide yield (Fukagawa and Ziska. 2019). To fulfill the demand of the increasing population by 2030, the world's rice production must be raised by at least 25%. Bangladesh, one of the Asian Mega Delta nations, contributes significantly to rice production and food security in the country as well as globally (Schneider P. and Asch F. 2020). The green revolution has enhanced crop yield by heavily utilizing chemical fertilizers, but fertilizers damage ecosystem health, and biodiversity (Khan *et al*. 2020). Increased agricultural land usage has detrimental effects on the environment and people's health, including deteriorating soil fertility and productivity (Kopittike*et al.* 2019). As a result, soils lose their reserves of soil organic matter (SOM), which impairs soil performance, its ability to provide crucial ecosystem services, and soil health (Lal. 2020). The organic matter content in an ideal soil should be about 5% in its volume, but in most soils in Bangladesh, it is getting to be very low. To sustain soil health integrated nutrient management can improve soil fertility and long-term crop productivity (Shrestha *et al.* 2020). Plants require all the essential nutrients in the right proportions for optimum development, growth, and production.

With accelerating the world shift to an urban future, municipal solid waste (MSW), is a significant by-product of urban lifestyle that is expanding faster than urbanization. According to World Bank research, there has been approximately 70% global growth in urban MSW, which leads nations to most difficulties (Meena*et al*. 2019). As a result of the high rates of organic waste generation and their open dumpsite in landfills, there are certain negative impacts on the environment, economy, and social life. One of the most eco-friendly methods for keeping organic contaminants out of landfills is composting (Erguven, G, and Kanat. G. 2020). Recycling waste through composting is an environmentally favorable substitute, which can be used as a source of plant nutrients(Almendro-Candel*et al.* 2019). The main objectives of sustainable waste management are resource conservation, protection of the environment, and human health. Goals also include preventing the export of issues related to trash into the future (Brunner *et al*. 2013) and maintaining long-term soil fertility (Brust. 2019)

Municipal solid waste contains high soil organic matter, which becomes more significant as an organic amendment for restoring soil fertility and enhancing soil biological, physical, and chemical properties. Compost made from municipal solid waste reduces the harmful effects of salt-affected soils and functions as a soil conditioner significantly enhancing crop production (Meena*et al*. 2019). The MSW compost amendment decreases bulk density while increasing soil porosity and stability against water erosion. In addition, compost-amended soils had higher pH values, total organic C and N contents, and accessible nutrients (Dominguez *et al.* 2019).Compost increases the CEC and AEC, nutrient availability, buffers the soil, neutralizes both acidic and alkaline soils, and stable pH levels to the ideal range for nutrient availability to plants for a longer period. Organic amendments can raise nutrient concentration, particularly NPK, organic carbon, microbial biomass, and enzymatic activity (Meena*et al.* 2016). Applying MSW compost to the soil properly helps to preserve soil and the environment by reducing the need for chemical fertilizers.

To reduce soil degradation and biodiversity loss caused by long-term usage of inorganic fertilizers another practical agricultural strategy is green manuring (Khan *et al.* 2020). To decrease the need for chemical fertilizers in cereal-based cropping systems legumes can be used as organic amendments (Achu*et al.* 2013). Green manures can be used to effectively restore soil fertility, it has significant effects on the soil's physical, chemical, and biological features. Green manure enhances soil nutrients by fixing atmospheric nitrogen in the soil as legumes, increasing the amount of organic matter, supply of nutrients, and controlling weeds (Das *et al.* 2020). Green manures has numerous benefits, including reducing erosion, increasing soil fertility, protect plants, and supply nitrogen to the following crops (Maitra*et al*. 2018). Green manures can continue to have positive benefits on soil quality, and overall yield of rice (Surekha*et al*. 2014).

The current study's objectives were to ascertain the long-term effects of MSW compost and green manure on rice.

a. To evaluate the residual effect of municipal solid waste (MSW) compost and Green manure (GM) on soil nutrient content
b. To assess the residual effect of municipal solid waste (MSW) compost and Green manure (GM) on nutrient uptake by rice.

BINA Dhan-7, a high-yield variety (HYV) of rice was used as a test crop in a Mungbean-Dhaincha-Rice cropping pattern field to know the residual effect of different doses of MSW compost, green manure, and mineral fertilizers.

2. MATERIAL AND METHODS

2.1 Experimental site and soil characteristics

A field experiment was carried out at the Soil Science Field and Laboratory of Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh (24^{o}56.11′ N, 89^{o}55.54′ E) during the Kharif-2 season from 05 August 2013 to 16 November 2013. Soils belonging to the Sonatola soil series of Non-calcareous dark gray floodplain under the AEZ-9: Old Brahmaputra Floodplain. The soil is AericHaplaquepts under the order Inceptisols (US Soil Taxonomy) and Chromic-EutricGleysols (FAO Soil Units). The experimental unit was under a subtropical humid climate and is characterized by a hot and humid climate and cold winter. The soil (0-15cm) texture was silt loam including fairly level topography in medium-high land.

2.2 Treatment details of the experimental setup

Nine treatments were randomly distributed within the blocks including control, fertilizers, *Rhizobium* inoculated green manure (GM), and municipal solid waste (MSW) compost in different combinations is as table 1.

Table 1. Treatment combinations applied in the experimental field

Treatment	Combinations
T_0	No fertilizer or MSW compost or green manure
T_1	RDF (Recommended dose of fertilizers, NPKS followed by rice),
T_2	GMR_1 (Green manures inoculated with *Rhizobium*-1 followed by rice + 100% PKS),
T_3	GMR_2 (Green manures inoculated with *Rhizobium*-2 followed by rice + 100% PKS),

T_4	GM R_{mix}(Green manures inoculated with mixed strains of *Rhizobium* followed by rice + 100% PKS),
T_5	GM $R_{mix}Com_{2.5}$ (Green manures inoculated with mixed strains of *Rhizobium* followed by rice + 75% PKS + compost 2.5 t ha^{-1}),
T_6	GM $R_{mix}Com_5$ (Green manures inoculated with mixed strains of *Rhizobium* followed by rice +75% PKS + compost 5 t ha^{-1}),
T_7	GM $R_{mix}Com_{7.5}$ (Green manures inoculated with mixed strains of *Rhizobium* followed by rice + 75% PKS + compost 7.5 t ha^{-1}),
T_8	GM $R_{mix}Com_{10}$ (Green manures inoculated with mixed strains of *Rhizobium* followed by rice + 75% PKS + compost 10 t ha^{-1})

Urea, triple superphosphate (TSP), muriate of potash (MP), and gypsum were used in the previous crops as the source of N, P, K, and S, respectively. The recommended dose of fertilizers was N 90 kg ha^{-1}, P 24 kg ha^{-1}, K 65 kg $ha^{-1,}$ and S 10 kg ha^{-1}. The experimental plots received MSW compost and fertilizers as per treatments in the preceding 2 cropping cycles. Well-decomposed MSW compost was incorporated into the soil as per treatments, 7 days before transplanting, and compost was mixed thoroughly with the soil. The first dose of urea was applied at 7 days after transplanting and rest at 30 and 60 days after transplanting of rice. P, K, and S were applied @ 20, 50, and 10 $kgha^{-1}$ from triple super phosphate (TSP), muriate of potash (MP), and gypsum, respectively, in all the plots except control as basal dose during final land preparation. In the case of the present rice crop, the plots didn't receive any fertilizer at all.

Randomized Complete Block Design (RCBD) was followed, where 3 blocks represented the replications to reduce the effects of soil heterogeneity. Each block was divided into 9 unit plots with raised dykes. The total number of the unit plot was 27 and each size was 4.0m × 2.5m plots were separated from each other by a 0.25m dyke. The blocks were separated from each other by 0.5m drains. Nine treatments were randomly distributed within the blocks.

2.3 Crop management

BINA Dhan-7, a short-duration high-yielding variety of rice released by the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh in 2007. It takes about 110 to 120 days from cultivation to harvest. The plant height is 90-95 cm and the cultivar is of a non-lodging type. It is somewhat resistant to pests and diseases, especially resistant to blast diseases. All kinds of intercultural operations were done properly such as plowing, leveling, weeding, irrigation, fertilization, Insect-pest control, and harvesting.The seedlings of rice were transplanted on 31 January 2013 maintaining a spacing of 25 cm x 15 cm. Three healthy seedlings were transplanted on each hill. Intercultural operations were done as per requirement for normal growth of the crop. The rice was harvested at full maturity. The harvested rice of each plot was bundled separately and bought to the threshing floor. Grain and straw yields were analyzed and recorded plot-wise.

2.4 Data collection and Nutrient analysis

The initial, as well as final soil samples from the surface (0-15 cm), were analyzed for mechanical composition, soil reaction (pH), electrical conductivity, organic matter content, and available nutrients (N, P, K, and S) following standard procedures. The grain, straw, and soil samples from every plot were chemically analyzed for N, P, K, and S concentrations. After the completion of two cycles of the Mungbean-Dhaincha-Rice cropping pattern soil samples from the surface (0-15 cm) were collected. In each plot, the soil was collected from ten points randomly, and mixed into one sample. After carefully removing the surface organic materials and fine roots, the soil samples were air-dried in shade, ground to pass through a 2-mm sieve, and used for the estimation of soil chemical properties. The physicochemical properties of the initial soil under study are presented in Table 2.

Table 2. The physicochemical properties and fertility status of the experimental soil before commencing the study

Soil characteristics	**Value (0-15 cm) soil depth**
Mechanical composition	
Sand (%)	10.25
Silt (%)	76.26
Clay (%)	14.25
Textural class	Silt loam
pH (soil: water:: 1:2.5)	6.34
CEC (me/100 g soil)	12.50
Organic matter (%)	1.04
Available P (ppm)	12.03
Exchangeable K (me/100 g soil)	0.11
Available S (ppm)	12.10

"Soil pH was determined by a pH meter with a soil water suspension 1:2.5 ratio" (Jackson *et al.* 1973). "Soil organic carbon was determined using $K_2Cr_2O_7$-H_2SO_4 wet oxidation method" (Walkley and Black, 1934). "The alkaline potassium permanganate oxidizable soil N

($KMnO_4$) as an index of available N was determined as per the procedure" given by Subbiah and Asija (1956). "Olsen-P was extracted with *0.5 M* sodium bicarbonate (pH 8.5) as outlined by (Olsen *et al.* 1954) and the P content in the extract was determined using ascorbic acid as a reducing agent (Watanabe and Olsen, 1965) by a spectrophotometer". "Available K (NH_4OAC-K) was extracted with neutral *1N* ammonium acetate (Hanway and Heidel, 1952) and estimated by a flame-photometer, while available S ($CaCl_2$-S) was determined by extracting the soil sample with 0.15% $CaCl_2$ (Williams and Steinbergs, 1959) and sulfur content in the extract was estimated by turbidimetric method" (Chesnin and Yien, 1950).

2.5 Statistical analysis

Data on the nutrient content and uptake were recorded. The collected data were analyzed statistically by F-test to examine whether treatment effects and the mean values were compared by Duncan's Multiple Range Test (DMRT) and ranking was indicated by letters (Gomez and Gomez, 1984). Collection and preparation of plant and soil samples, data collection, and analysis were done. The software package, MSTATC was followed for statistical data analysis. The chemical analysis of grain and straw samples, and nutrient uptake were calculated as follows:

Nutrient uptake (kg ha^{-1}) = $(G_y x\ N_{Gr})/100 + (S_y\ x\ N_{st})/100$

3. RESULTS

3.1 Residual effect of MSW compost and green manures on the nutrient content of BINA Dhan-7

3.1.1 N Content

Nitrogen content in the grain and straw of BINA Dhan-7 increased significantly due to the residual effect of MSW compost and green manures. The nitrogen content in rice grain ranged from 1.09% to 1.32 %. The highest N content of 1.32% was observed in treatmentT_8 (GM R_{mix}+ com_{10}) and the treatments T_5, $T_{6,}$ $T_{7,}$ and T_8 observed significantly higher N content compared to all others. The lowest N content of rice grain 1.09% was recorded in the control treatment, T_0. The N content of rice straw also varied significantly due to different treatments and ranged from 0.40 to 0.53%. The treatmentT_8 noted the highest N content in rice straw with values of 0.53%. The treatments $T_{5,}$ $T_{7,}$ andT_8 exerted a statistically significant effect than all others. The N content in the straw of Binadhan-7 was comparatively lower than that in rice grain. All the MSW compost and green manure amended treatments recorded significantly higher N content in the grain of Binadhan-7 compared to the fertilizer treatment T_1. Besides treatments composed of both MSW compost and GM shows higher N content in grain and straw compared to the GM treatments and fertilizers (Table 3).

3.1.2 P Content

The phosphorus content in rice grain due to different treatments ranged from 0.109% to 0.132%. The highest P content of 0.132% in rice grain was observed in treatmentT_7 and the minimum value of 0.109% was noted in the T_0, treatment. The treatments$T_{6,}$ $T_{7,}$ andT_8were statistically identical in terms of P content in rice grain with the values of 0.130, 0.132, and 0.131 and statistically different from others. All the treatments recorded higher P content in rice grains over the treatments T_1. The P content in rice grain was comparatively higher than that in rice straw. The P content in rice straw also varied significantly and ranged from 0.029 to 0.048% (Table 3). The maximum P content 0.048% in rice straw was recorded in the treatment T_8 (GM R_{mix}+ com_{10})which is statistically significant to others as well as the control treatment. The treatments with higher doses of MSW compost and GM shows higher P content in grain and straw (Table-3).

Table 3. The residual effect of MSW compost and green manures on the N and P content of grain and straw of BINA Dhan-7

Treatment	Nitrogen (%)		Phosphorus (%)	
	Grain	Straw	Grain	Straw
T_0	1.09^{e}	0.40^{e}	0.109^{f}	0.029^{g}
T_1	1.15^{de}	0.48^{c}	0.115^{d}	0.035^{f}
T_2	1.18^{cd}	0.42^{de}	0.112^{e}	0.037^{ef}
T_3	1.22^{bcd}	0.50^{bc}	0.121^{b}	0.041^{cd}
T_4	1.19^{cd}	0.43^{d}	0.118^{c}	0.039^{de}
T_5	1.25^{abc}	0.51^{ab}	0.121^{b}	0.044^{bc}
T_6	1.30^{ab}	0.50^{bc}	0.130^{a}	0.044^{bc}
T_7	1.24^{abc}	0.51^{ab}	0.132^{a}	0.045^{b}
T_8	1.32^{a}	0.53^{a}	0.131^{a}	0.048^{a}
$LSD_{0.05}$	0.077	0.023	0.002	0.003
Level of significance	**	**	**	**
CV (%)	3.64	2.83	1.12	4.31

Figures in a column having common letters do not differ significantly at a 5% level of significance. CV% = Coefficient of variation. LSD = Least Significant Difference

3.1.3 K Content

Potassium content in the rice grain of Binadhan7 varied significantly due to the residual effect of MSW compost and green manures and ranged from 0.120% to 0.161%. The maximum K content in rice grain 0.161% was found in treatment T_5. Treatments T_5 and T_8 observed significantly higher K content than others followed by T_3, $T_{6,}$ and T_7. In straw, a residual effect of MSW compost and green manure influenced the K content significantly and the values of K due to different treatments varied from 1.29 to 1.66%. The maximum K content in rice straw 1.66% was found in treatment T_8 (GM R_{mix}+ com_{10}) followed by the treatment $T_{7,}$ T_6, and T_5 which are statistically significant to others. The control treatment recorded the lowest K content in rice straw 1.32%. All the treatments recorded higher K content in rice grains over the treatments T_1 except the treatments T_2 and T_0. The residual effect was more pronounced in treatments receiving higher rates of MSW compost(Table 4).

3.1.4 S content

The S content in rice grain ranged from 0.242% to 0.352%. The maximum S content in rice grain 0.352% was found in the treatment T_8 (GM R_{mix}+ com_{10}). In terms of S content in rice grain treatment$T_{6,}$ $T_{7,}$ andT_8 are significantly higher than others. In straw, the S content ranged from 0.237 to 0.322%. The maximum S content in rice straw 0.322% observed in the treatment was T_8 (GM R_{mix}+ com_{10}) which was statistically identical to that of the treatment T_7 followed by the treatment T_6. The lowest S content in rice grain and straw was observed in the control treatment. The residual effect of S content in both grain and straw was more pronounced in treatments receiving higher rates of MSW compost (Table 4).

Table 4. The residual effect of MSW compost and green manures on the K and S content in grain and straw of BINA Dhan-7

Treatments	Potassium (%)		Sulfur (%)	
	Grain	Straw	Grain	Straw
T_0	0.120^{e}	1.29^{e}	0.242^{e}	0.237^{e}
T_1	0.130^{d}	1.40^{d}	0.255^{e}	0.243^{e}
T_2	0.120^{e}	1.33^{de}	0.287^{d}	0.248^{e}
T_3	0.150^{b}	1.55^{bc}	0.301^{c}	0.266^{d}
T_4	0.140^{c}	1.50^{c}	0.310^{bc}	0.288^{c}
T_5	0.161^{a}	1.58^{abc}	0.322^{b}	0.303^{b}
T_6	0.150^{b}	1.60^{ab}	0.345^{a}	0.311^{ab}
T_7	0.150^{b}	1.62^{ab}	0.350^{a}	0.320^{a}
T_8	0.160^{a}	1.66^{a}	0.352^{a}	0.322^{a}
LSD	0.009	0.086	0.016	0.014
Level of significance	**	**	**	**
CV (%)	3.61	3.30	2.99	2.82

Figures in a column having common letters do not differ significantly at a 5% level of significance. CV% = Coefficient of variation. LSD = Least Significant Difference

3.2 Residual effect MSW compost and green manures on the nutrient uptake by grain and straw of BINA Dhan-7

3.2.1 N uptake

The N uptake of rice grain ranged from 28.47 to 45.13 kg ha^{-1} and that of rice straw from 14.60 to 27.47 kg ha^{-1}. The highest N uptake of grain 45.13 kg ha^{-1} and straw 27.47 kg ha^{-1} was obtained in the treatment T_8 (GM R_{mix}+ com_{10})and the corresponding lowest values of 28.47 kg ha^{-1} and 14.60 kg ha^{-1} respectively were found in the control treatment T_0. The total N uptake of rice straw was also influenced significantly due to different treatments and ranged from 28.47 to 72.6 kg ha^{-1}. The highest total N uptake 72.6 kg ha^{-1} was observed in the treatment T_8 (GM R_{mix}+ com_{10}) and the lowest value 43.07 kg ha^{-1} was found in the control treatment T_0 (Fig 1).

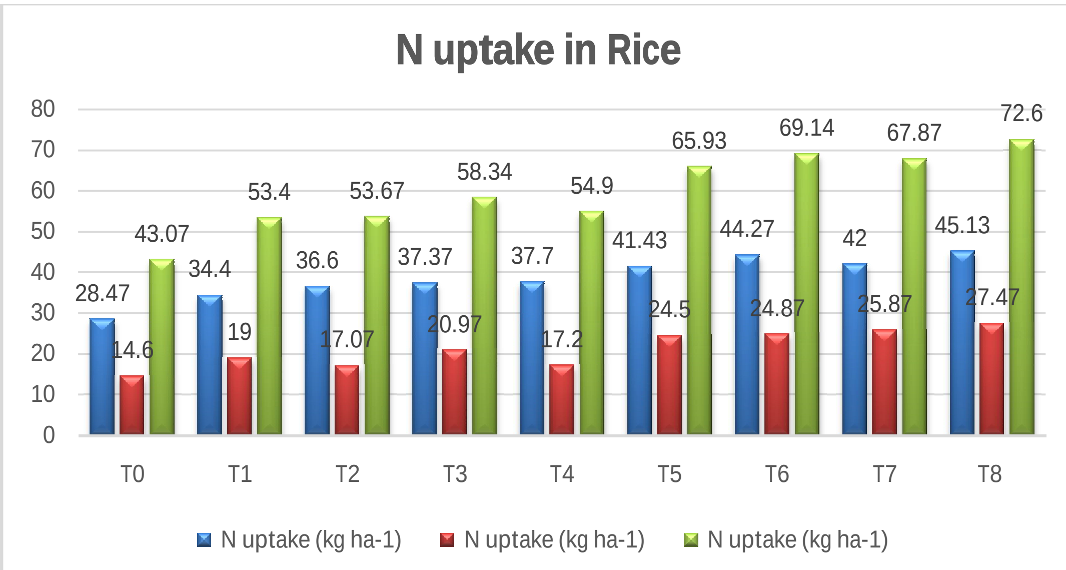

Fig 1. Grain, straw, and total residual N uptake by rice

3.2.2 P uptake

A significant variation in P uptake by BINA Dhan-7 was observed due to the various treatments (Fig 2). The P uptake of rice grain ranged from 3.260 to 4.473 kg ha^{-1} and that of rice straw from 1.060 to 2.490 kg ha^{-1}. The highest P uptake of rice grain 4.473 kg ha^{-1} was obtained in treatmentT_7 and that in straw 2.490 kg ha^{-1} was obtained in treatment T_8. The corresponding lowest values of 3.260 kg ha^{-1} and 1.060 kg ha^{-1}, respectively were found in the control treatment T_0.The total P uptake by rice grain and straw was significantly higher in treatments with different doses of MSW compost. The highest total P uptake 6.753 kg ha^{-1} was observed in treatment T_7 (GM R_{mix}+ $com_{7.5}$) and the lowest value 4.32 kg ha^{-1} was found in the control treatment T_0 (Fig 2).

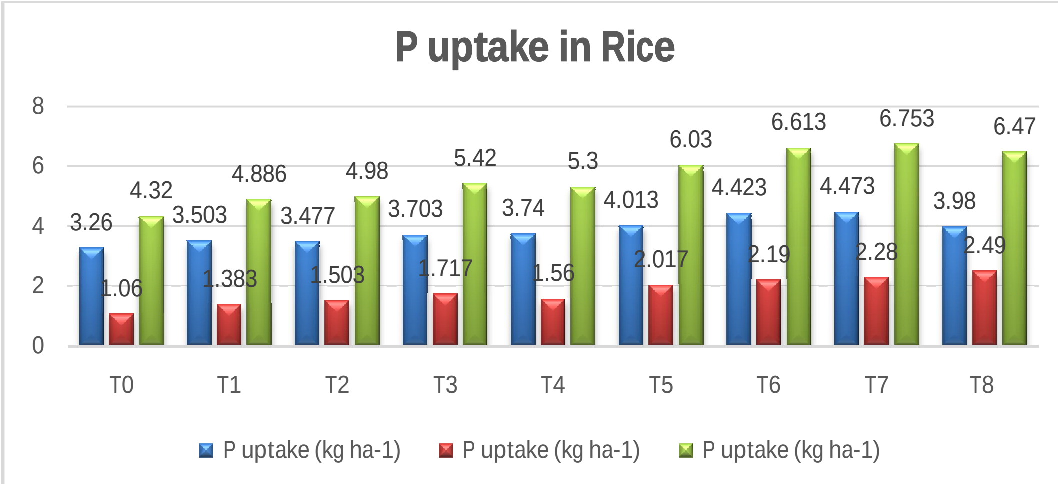

Fig 2. Grain, straw, and total residual P uptake by rice

3.2.3 K uptake

The K uptake of rice grain ranged from 3.13 to 5.57 kg ha^{-1} and that of rice straw from 4.71 to 8.61 kg ha^{-1} was observed. The highest K uptake by rice grain 5.57 kg ha^{-1} and straw 8.61 kg ha^{-1} was obtained in the treatment T_8 (GM R_{mix}+ com_{10}) and the lowest value in grain 3.13 kg ha^{-1} and straw 4.71 kg ha^{-1} was noted in the control treatment T_0. The total K uptake of rice grain and straw was also influenced significantly by different treatments. The highest total K uptake 14.08 kg ha^{-1} was observed in the treatment T_8 (GM R_{mix}+ com_{10}) and the lowest value 7.84 kg ha^{-1} was found in the control treatment, T_0 (Fig 3).

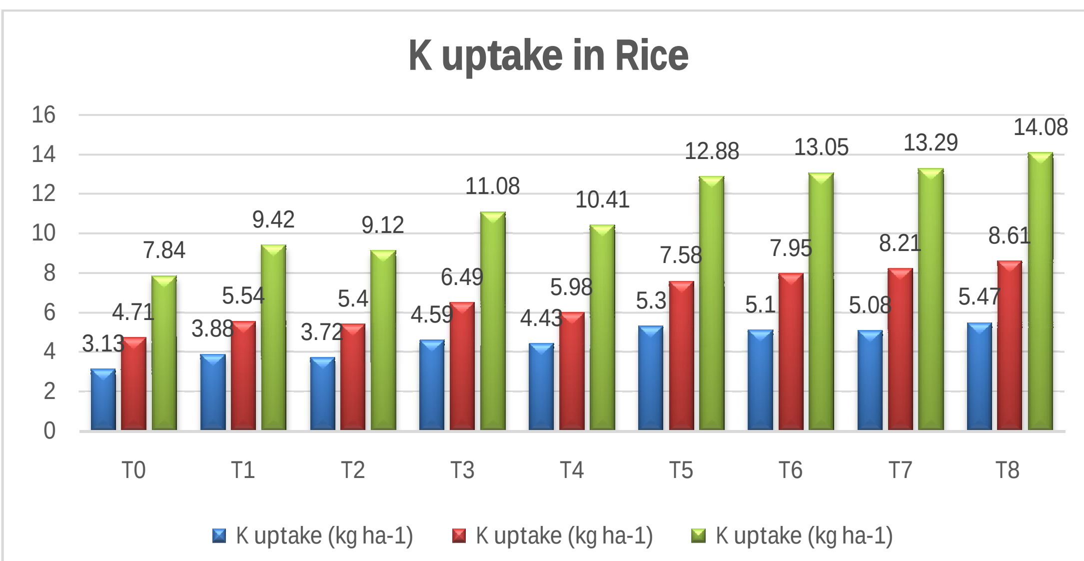

Fig 3. Grain, straw and total residual K uptake by rice

3.2.4 S uptake

The S uptake of rice grain ranged from 0.6320 to 1.204 kg ha^{-1} and that of rice straw from 0.8650 to 1.670 kg ha$^{-1.}$ The highest S uptake by rice grain 1.204 kg ha^{-1} and straw 1.670 kg ha^{-1} was obtained in the treatment T_8 (GM R_{mix}+ com_{10})and the lowest S uptake by grain 0.6320 kg ha^{-1} and straw 0.8650 kg ha^{-1} was found in the control treatment T_0. The total S uptake by rice grain and straw was also influenced significantly by different treatments (Fig 5). The highest total S uptake 2.874 kg ha^{-1} was observed in the treatment T_8 (GM R_{mix}+ com_{10})and the lowest value 1.497 kg ha^{-1} was found in the control treatment T_0. Total S uptake was higher with MSW compost and GM-treated plots compared to fertilizers-treated plots and control (Fig 4).

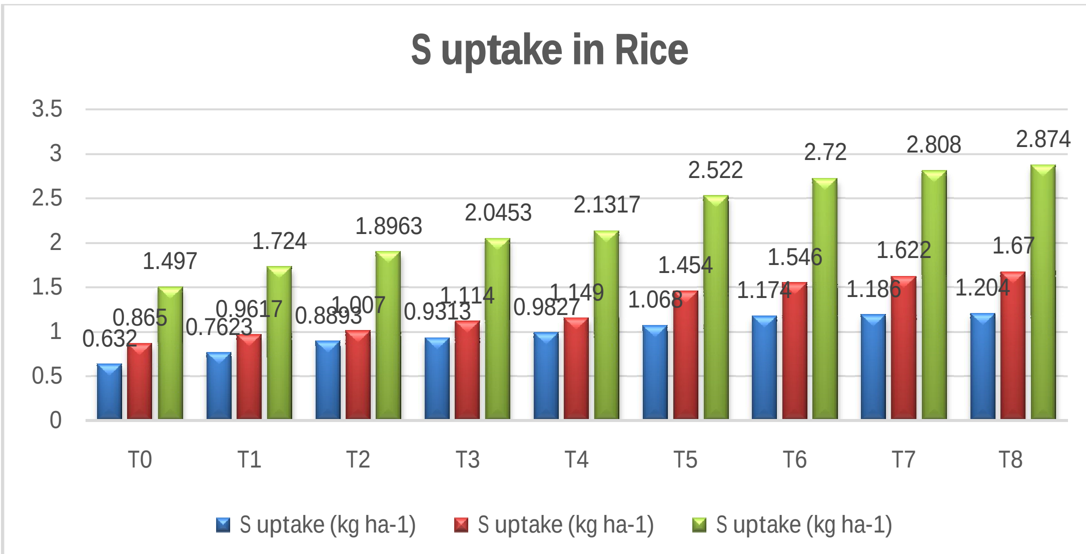

Fig 4. Grain, straw, and total residual S uptake by rice

DISCUSSION

The general recommendations that emerged from the present study were i) Application of both MSW compost and GM in the previous crop has considerable effects on the nutrient content of the soil, ii) Both MSW compost and GM increase the soil nutrient contents as well as uptake of the present crop (BINA Dhan-7), iii) For both residual effects were more treatments receiving compost at higher rates in the preceding crops. Only a small portion of the nitrogen in mature compost becomes available in the first year because composts release nutrients slowly, especially nitrogen (Sayara*et al.,* 2020). When the organic material in the MSW compost undergoes intensive mineralization, a large amount of nitrogen liberates. After the completion of the composting process, the majority of the nitrogen is bonded into organic forms and is not immediately available to plants for uptake. This is partially caused by nitrogen being immobilized by soil microbes with a very low C: N ratio, which leads to poor nitrogen linkage. Moreover, a significant amount of nitrogen often remains in the soil's humus for years before becoming available to the following crops (Brust, 2019).MSW compost consistently increases soil organic matter content and soil C: N ratio (Montemurro*et al*. 2006; Civeira. 2010) which depends on the nature of composting material, maturity of compost, rate of application, and mineralization rate.

Repeated application of organic amendments can increase soil organic carbon, microbial biomass, enzymatic activities (Meena*et al.*2016), microbial biomass carbon, and basal respiration. They serve as a source of energy for microorganisms, boost the availability and concentration of nutrients in the soil (Rekaby*et al.,* 2020, Sultana *et al.,* (2021), and release nutrients in a manner easily absorbed by plants (Shaji*et al.* 2021). They can increase soil structure, aeration, electrical conductivity (Ros*et al*. 2006; Becker *et al.* 2010), aggregate stability, and decrease bulk density(Diacono and Montemurro, 2015), preventing root burn and leaching losses. Similar findings were observed by Grigatti*et al.* (2017) organic manure increases P availability and uptake by plants. Compost made from maize straw and sewage sludge can raise the soil pH, beneficial microorganisms,and decrease the number of harmful microorganisms, and encourage crop growth (Ding *et al.* 2021). Increased microbial activity and functionality from MSW compost can also stabilize potentially harmful components in sub-acidic polluted soils (Garau*et al.* 2019). Sayara*et al*. (2020) reported that compost application can increase soil organic carbon three-fold and microbial activity double.

By adding organic matter to the soil, compost improves soil macronutrient levels that support plant metabolism and raises long-term soil productivity. Composts containing high amounts of available nitrogen (N) often result in more rapid plant growth and yield, whereas composts with more N bound up in the organic fraction exhibit surplus growth response over successive seasons. (Nweke*et al.* 2018).Zhang *et al.* (2016) demonstrated that after three years of compost treatment, especially in the second and third years grain yield increase.Sultana *et al*. 2020 reported that MSW compost inoculated with Trichoderma has a great way to improve the soil nutrient status (N, P, K, and S), soil fertility, and crop productivity which left a long impact on the soil. Similar findings were reported by Queriemmi*et al.* (2021) MSW compost with sewage sludge compost acts as a source of nutrients, it has a beneficial residual effect on nutrient contents in soil, and finally yields (increases up to 77%). Elshony*et al.* (2019) also observed that the effects of biochar and compost on the physical and chemical properties of soil greatly increase the availability of macro and micronutrients, boost plant uptake of those nutrients, and have lingering effects throughout seasons. With the increase in compost application rate used in the previous year existing crop yield increased significantly (Jackson *et al*. 2013). MSW compost can be considered a slow-release provider of nutrients that enhance the overall features of the soil, and yield of the present crop and also remains as residue which positively affects the following crops (Fig. 5).

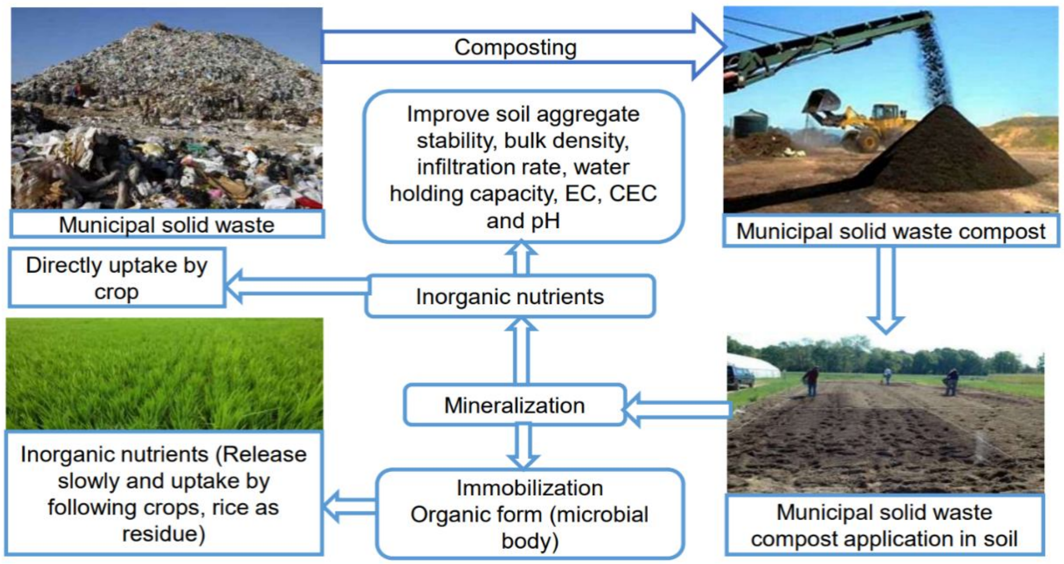

Fig. 5 Schematic diagram showing recycling the municipal solid waste (MSW) as compost, application to soil, the portion used by the present crops, and residual effects on following crops (Rice)

The bacterial strain-inoculated green manures have a good impact on soil nutrient content and crop uptake. Similar findings were reported by Singh *et al*. (2019) in a two-year trial, GM crops with fertilizers considerably raise the nutrient content of rice grain and straw during both years. Khan *et al.* (2020) suggested that GM amendment significantly increases the amount of the soil's microbial community, which produces a variety of extracellular enzymes and degrades soil organic matter.GM affects the physicochemical characteristics of soil, the activity of soil enzymes, and the nutritional condition of the soil (Tang *et al.* 2014)**.**Only a small to moderate amount of nitrogen from green manure is used by the following crop (Gautam*et al.* 2021) but most amounts remain in the soil as residue. Sole applications of manure or fertilizer cannot maintain soil health and crop productivity, but integrated strategies have been shown to greatly improve soil fertility, crop quality, and yield (Kavitha and Subramanian, 2007; Youssef and Eissa, 2017; Aktar*et al.* 2018). Composting organic waste in agriculture can reduce the need for chemical fertilizers and enhance the physical, chemical, and biological characteristics of the soil (Cambier*et al.* 2014) and overall soil quality (Eghball*et al.* 2004).

The nutrient content in soil and uptake in rice tended to increase as MSW compost application rates increased in the previous crop. The application of MSW compost and green manure does not replace chemical fertilization but is used in association with fertilizers can satisfy the necessity of crop nutrients. The benefits to the soil of adding compost can increase longer-term soil productivity and show more carry-over growth response in subsequent seasons.

CONCLUSIONS

Application of Municipal Solid Waste compost and incorporation of green manure exerted a considerable residual effect on the nutrient content in soil and uptake in grain and straw of rice. The residual crop yield benefits through nutrient content and uptake from soil were only apparent when 10-20 tons of compost was applied in the previous year. Nutrient content in soil and uptake in rice increase as compost application rates increased. The benefits to the soil of adding organic matter as well as N with compost can increase longer-term soil productivity. Composts with high levels of available N tend to show more immediate plant response in terms of growth and yield, while compost with more N tied up in the organic fraction shows a carry-over growth response in subsequent seasons. However the composition of MSW composts is important, it may contain some heavy metals also along with nutrients. Further study on the effect composition of amendments on heavy metal concentration in soil should be needed.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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